ANALYSIS OF GROUND REACTION FORCE IN A GYM MOVEMENT

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INTRODUCTION

Physical fitness or physical condition is composed by these components: aerobic resistance, local muscle resistance, strength, flexibility, and body composition. Gym workout has the purpose of obtaining physical condition of its participants (Santos, 1994).

Four were the methods that influence gym workout: calisthenics, aerobics, step training, and muscle resistance training (Neto e Novaes, 1996) and today lots of variations of these methods, but with the same purpose, can be verified at the gyms. The physical exercises used at gym are aerobic and anaerobic exercises. The aerobic ones have the objective to provoke cardiovascular and respiratory systems adaptations, especially in sedentary subjects and non-athletes, enhancing oxygen absorption, transport, delivery, and utilization by the muscles (Santos, 1994). Aerobic exercises are used as well to develop general muscle resistance and for learning and enhancement of motor abilities like marching, running, hopping, skipping, dancing, among others (Guiselini, 2001).

One of the gymnastics exercises is the march. It is a basic and easy exercise and is used in all levels of classes (beginners, intermediate, and advanced). It is a cyclic movement that can be described as an exercise where both arms move in flex and extension movements, maintaining the elbow joint flexed, and both legs move flexing and extending the hip and knee joints, so that when one leg is flexed the other one is extended. In this movement one foot is always in touch with the ground.

The tendency to popularize physical activity, besides the known benefits for health promotion and maintenance, has caused an undesirable consequence: the enhancement of injuries (Serrão, 2002). According to Hamill & Knutzen (1999), 43% of the participants and 76% of the high impact aerobic instructors have injuries.

Among the factors that could be the cause of injuries in aerobics exercise, we could point out the magnitude of the ground reaction force. Great part of the injuries that occur in aerobics exercise are due to the overload imposed to the joints affecting specially inferior extremities (Neto & Novaes, 1996).

In face of what was exposed, this study has the purpose to analyze the behavior of the ground reaction force in the march in three different cadencies.

METHODS

The sample was chosen intentionally and was composed by eight female subjects aged between 18 and 24 years old, with a height mean of 1.65 ± 0.06 m and a weight mean of 569.90 ± 60.76 N, that belonged to the community of Florianópolis, Brazil. The sample showed up using their gymnastics shoes. The data was collected in the Biomechanics Laboratory of the Physical Education, Physiotherapy and Sports Center from Santa Catarina State University – UDESC.

For the data acquisition, two AMTI (Advanced Mechanical Technology, Inc.) force plates were used with acquisition frequency of 900 Hz and acquisition time of 4 s. The data were processed by software developed in IDL (Interactive Data Language).

It was asked that the subjects stood on the plates with one foot on each one of them and had the movement done in three different cadences: 130, 140, and 160 bpm (beats per minute). These cadences were marked by music and were chosen according to class levels. The cadence of 130 bpm is used in beginners level, the cadence of 140 in intermediate level, and the cadence of 160 in advanced level. Three trials in each cadence were realized. The subjects had a time to adapt to the place and with the cadence before the signs were recorded, and between trials in the same cadence the subjects had the movement done with no interval.

The variables studied were: first peak of vertical force (Fy 1), second peak of vertical force (Fy 2), stance time (Δt) time of the first peak of vertical force (Δt Fy 1), time of the second peak of vertical force (Δt Fy 2), and loading rate (LR). Fy 1 corresponds to the first peak of vertical force, Fy 2 to the second peak of vertical force, Δt to the duration of the stance phase, that is, the time between the foot touching on the plate and leaving it, Δt Fy 1 corresponds to time that occurred the first peak of vertical force, Δt Fy 2 corresponds to the time that occurred the second peak of vertical force, and LR corresponds to the force increase until it attained the first peak of vertical force related to the time of the first peak of force. The variables corresponding to the ground reaction force were normalized by body weight (BW) and the time variables were normalized by the stance time. Figure 1 shows graphically the definition of these variables.

![Figure 1: Curve of the vertical ground reaction force and variables studied: Fy 1 (a), Fy 2 (b), Δt (c), Δt Fy 1 (d), Δt Fy 2 (e), and LR (a/d).](image-url)
RESULTS AND DISCUSSION

The normality of the data was verified by the Shapiro-Wilk test. The results between the right and left foot did not show any statistically significant difference, verified by the Student’s t test and were analyzed together. The data was submitted to descriptive statistics and to compare the variables in the different cadences, variance analysis was used (ANOVA). In the cases where differences between the means were found, a Tukey test was used. The significance level used was 0.05.

Table 1 shows the results referent to the means and standard deviation obtained in the three cadences. Statistically significant differences were found in Fy 1 between cadences of 130 and 160 bpm and between 140 and 160 bpm. Between cadences of 130 and 140 bpm, no significant difference was found. In relation to the Fy 2, there was a significant decrease between cadences of 130 and 160 bpm and there was no statistically significant difference between cadences of 130 and 140 bpm and between 140 and 160 bpm. \( \Delta t \) presented statistically significant differences between all studied cadences. As to \( \Delta t \) Fy 1, there were differences only between cadences of 130 and 160 bpm, while in \( \Delta t \) Fy 2 there was a significant difference between cadences of 130 and 160 bpm and between 140 and 160 bpm. There was a significant difference in loading rate between 130 and 160 bpm cadences and between 140 and 160 bpm. It was observed that with the increase of cadence there was also an increase in the magnitude of Fy 1, which does not agree with Zebas & Klausner’s (1996) study involving three aerobic step movements, in which impact force in three cadences was compared: 120 bpm, 128 bpm and 135 bpm. The authors observed that the step movements could be conducted in cadences quicker than 135 bpm without enhancing impact force. They also observed that the impact force for the movements used and in the three cadences did not seem to be greater in relation to the fast walking or slow skipping.

In the 130 bpm cadence, the greater force peak was around 1.09 BW, in 140 bpm cadence it was around 1.11 BW and in the 160 bpm cadence it was around 1.16 BW, values found in Fy 1. The vertical force data of this study agree with the references where values for human gait varying between 1.0 and 1.2 BW were found (Hamill & Knutzen, 1999) and 1.25 BW (Durward, Baer & Rowe, 2001). These data were inferior compared to results of another gait study that found values of 1.52 ± 0.08 BW (Serrão & Amadio, 2001), and to aerial movements of the aerobic dance that vary between 1.96 and 2.62 BW (Ricard & Veatch, 1994).

Table 1: Mean and standard deviation of variables in the three cadences studied.

<table>
<thead>
<tr>
<th>Cadence (bpm)</th>
<th>Fy 1 (BW)</th>
<th>Fy 2 (BW)</th>
<th>( \Delta t ) (s)</th>
<th>( \Delta t ) Fy 1 (%)</th>
<th>( \Delta t ) Fy 2 (%)</th>
<th>LR (BW/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>1.09 ± 0.06*</td>
<td>0.92 ± 0.05*</td>
<td>0.74 ± 0.08*</td>
<td>0.40 ± 0.06*</td>
<td>0.70 ± 0.03*</td>
<td>2.80 ± 0.48*</td>
</tr>
<tr>
<td>140</td>
<td>1.11 ± 0.11*</td>
<td>0.91 ± 0.07**</td>
<td>0.68 ± 0.08**</td>
<td>0.39 ± 0.06**</td>
<td>0.71 ± 0.04*</td>
<td>2.90 ± 0.53*</td>
</tr>
<tr>
<td>160</td>
<td>1.16 ± 0.19**</td>
<td>0.90 ± 0.07**</td>
<td>0.59 ± 0.05**</td>
<td>0.38 ± 0.07**</td>
<td>0.72 ± 0.03**</td>
<td>3.13 ± 0.80*</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The results of this study demonstrated that the curve pattern of vertical ground reaction force in marching presented some similarities to the gait curve. As in human gait, the march curve presented two maximal peaks and one minimal peak, but the minimum peak was less accentuated. It was also observed that the first peak of vertical force happened later, approximately at 40 % of the stance phase (Figure 2). The mechanical solicitation imposed to body structures was not superior to the one imposed by walking, because the maximal values of vertical force were similar or inferior to the ones found in gait. The study also demonstrated that an increase in cadence tend to increase the first peak of vertical force, and to decrease the second peak of vertical force.

Figure 2: Mean curve of vertical ground reaction force in marching, obtained in this study, and human gait pattern, obtained from Serrão & Amadio (2001).

REFERENCES


